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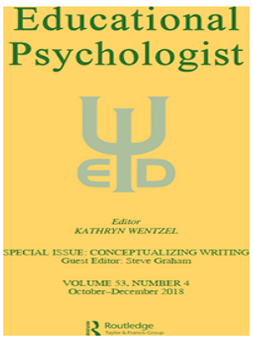

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The Work of Writing: Raiding the Inarticulate

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This article proposes that two processes are involved in the generation of content during writing: (a) an active, knowledge-constituting process in which content is synthesized by constraints within semantic memory representing the implicit structure of the writer's understanding, and (b) a reflective, knowledge-transforming process in which content retrieved from episodic memory is manipulated in working memory to satisfy rhetorical goals. It suggests that, although both processes are required for effective writing, the contrasting nature of the implicit organization guiding the constitution of the writer's understanding and the explicit organization required to satisfy rhetorical goals is the source of a fundamental conflict in writing. The article starts by relating the processes to current models of writing. It outlines how they are combined in a dual-process model and discusses evidence for the model. The article concludes with a discussion of the implications for writing research and the teaching and development of writing.

Writing is never easy. Maybe, in an ideal world, it could be easier if we were more self-regulated people and all our skills were perfectly honed. Then, perhaps, we could, like generals, marshal our cognitive troops dispassionately and efficiently to achieve our goals. Of course, this would still involve a lot of effort—generals are busy people—but writing well would essentially be a matter of directing this effort strategically to get things done as efficiently as possible. There is a lot of truth in this metaphor, and learning how to be more like this does indeed help people to write better. In this article, however, we argue that there is also a different kind of difficulty to writing and that it is intrinsic to the process. It arises from the implicit nature of much of our knowledge. The content that we write about is not pre-stored, waiting only on us to decide how best to deploy it, but is instead something that is constituted as we write. And the process of constituting this content is not straightforward but is instead a matter of trying to capture our understanding as it unfolds in the text. Writing, to use T. S. Eliot's phrase (Eliot, 1944), is a raid on the inarticulate, and it is integrating this process with the more strategic aspects of writing that is the work of writing.

In this article, we argue that the implicit nature of much of our knowledge has been neglected in research on writing because, like research on language production in general, it has focused on the processes that take place after content has been generated. After summarizing the key features of the cognitive processes involved in writing as they are currently conceived, we present an account of how knowledge is constituted in writing, situate this in relation to the other processes involved, and then discuss the implications for research and practice.

The classical models of the cognitive processes in writing developed in the 1980s (Bereiter & Scardamalia, 1987; Flower & Hayes, 1980a, 1980b) still form the basis for the assumptions that inform current research and its application to the teaching of writing. The enduring aim of these models has been to identify the basic processes involved in writing and to represent how these can be combined. Hayes and Flower's original model (Flower & Hayes, 1980b; Hayes & Flower, 1980, 1986) characterized the writing process as involving the three basic

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processes of planning, translating, and reviewing. Planning involved generating and organizing ideas to satisfy the writer's goals, translating involved formulating ideas in words, and reviewing involved reading and editing previously produced text. Individual differences in the way processes were combined were represented by a monitor, which specified the sequence in which the processes were carried out.

The original Flower and Hayes model (Flower and Hayes 1980b) had three key features. First, the writing processes did not correspond to stages in the writing process. Rather, the processes could occur at any time during the overall process. Second, the entire process was goal directed. Indeed, this was the fundamental way in which the process was controlled. Planning was divided into three types (Hayes & Nash, 1996): process planning, which was concerned with managing the writing process; content planning, which was concerned with retrieving and organizing content; and rhetorical planning, which was designed to ensure that the text's content, organization, and style achieved the writer's communicative goals. Third, the writing process took place within a limited capacity system, and the fundamental source of conflict in writing was characterized as cognitive overload. Strategies for drafting text were thought of as methods for reducing cognitive overload by focusing on different components of the writing process at different points during writing.

Overall, this model characterized writing as a problem-solving activity, in which writers tried to combine the component processes of writing as efficiently as possible to satisfy their rhetorical goals. Research showed that experts developed more elaborate representations of the rhetorical problem, planned and revised more extensively, and produced text in larger sentence parts than novices (Hayes & Flower, 1986). Flower and Hayes (1980a) further suggested that differences in the extent to which writing was directed toward rhetorical goals were responsible for expert characterizations of writing as a process of discovery. Developing and then solving rhetorical problems leads to moments of insight that are responsible for subjective changes in the writer's understanding of the topic. Bereiter and Scardamalia (1987) characterized this difference between novice and expert writers as a contrast between a knowledge-telling model of writing and a knowledge-transforming model of writing. Knowledge telling is equivalent to the generation and translation components of Flower and Hayes's (1980a) model and characterizes the process by which content is retrieved from long-term memory and translated into words. Whereas novice writers immediately translate content retrieved from memory, experts' translation is more deliberately controlled and involves the generation and evaluation of content with respect to rhetorical goals before translating it into words. The result is that experts both write more effectively and transform their knowledge during writing.

Although most research in the field still uses the basic terms of planning, translating, and reviewing to characterize basic writing processes, this is one of the major features that has changed as the model has evolved. Hayes's most recent model of the writing process (Hayes, 2012; see Figure 1), retains the overall characterization of writing as a goal-directed problem-solving activity, but planning and revision processes are no longer treated as basic processes and have disappeared, along with the monitor.

The basic processes are now conceived more simply in terms of the processes included in Chenoweth and Hayes's (2003) model of text production. The "Proposer" is responsible for the generation of ideas for expression; the "Translator" converts the proposed ideas into linguistic strings (in phonological form); the "Transcriber" converts the linguistic strings into text; and the "Evaluator" monitors the output of each of these processes, enabling revision of ideas, language, and written text. Writing activities like planning and revision now depend on how control processes call on, and use, the basic processes. Making a written plan, for example, involves all four processes but with different goals and criteria for linguistic output compared to the production of full text; revision may primarily involve evaluating written text, but in addition can involve all four writing processes when major revisions are made.

Apart from the reorganization of the basic components, the model reflects two main developments from the original Hayes and Flower model: the incorporation of working memory as a resource to reflect its centrality in the writing process (Kellogg, 1996; Olive, 2014) and the inclusion of transcription skills (principally spelling and motor processes) as a separate component of the writing process. These are important additions because they reflect key ingredients of the models of development that inform the design of writing instruction. For example, the "simple view of writing" (Berninger et al., 2002) characterizes writing development in terms of three components—transcription, text generation, and executive functions (including planning, reviewing, and strategies for self-regulation)—which compete for the limited resources of working memory (see also Kellogg, 2008). Accordingly, writing instruction has focused on improving the efficiency with which these skills are carried out and on clarifying a writer's understanding of the goals of writing, with a view to enabling younger writers to focus on appropriate goals in writing without being impeded by the need to devote resources to the component skills. There is a wealth of evidence of the effectiveness of instructional interventions informed by these models (Berninger, Abbott, Abbott, Graham, & Richards, 2002; Graham & Harris, 2000; Graham, McKeown, Kiuhara, & Harris, 2012; Kent & Wanzek, 2016; McCutchen, 2000).

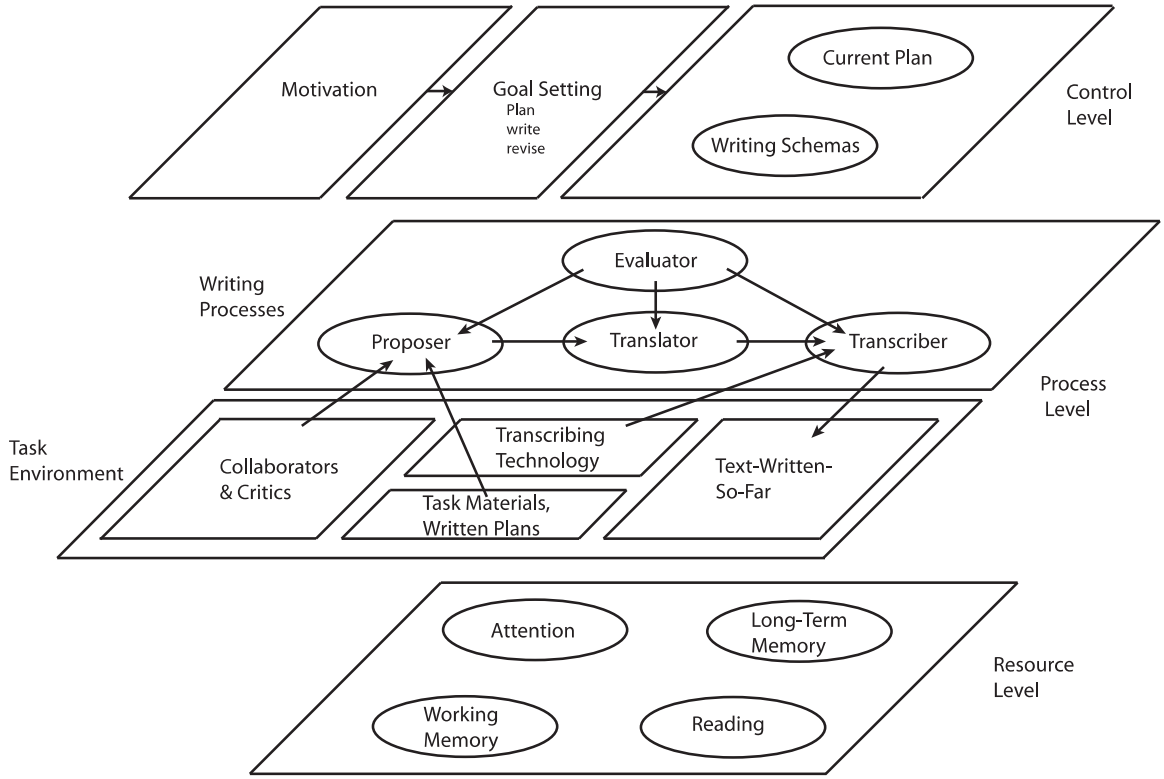

FIGURE 1 Hayes's revised model of the writing process. From "Modeling and Remodeling Writing" by J. R. Hayes, 2012, *Written Communication*, Vol. 29, No. 3, p. 371. © Sage. Reproduced by permission of Sage. Permission to reuse must be obtained from the rightsholder.

Problematic Features of the Model

The striking feature of these models is how little they have to say about how knowledge is represented. Their general assumption is that knowledge in long-term memory is explicitly represented as declarative knowledge and that it is retrieved from memory before being translated into words. The focus is on how the writer's goals and plans guide the selection of content from memory and on how this content is evaluated and refined as it is turned into text. The one exception to this lack of discussion is an article by Flower and Hayes (1984) discussing the different types of representation constituting a writer's knowledge and giving as an example the semantic network described by Collins and Quillian (1969), in which knowledge is explicitly represented in a propositional network.

The problematic nature of this assumption was acknowledged by Bereiter and Scardamalia (1987), who pointed out that "one of the most formidable challenges to theories of language use is to explain how it is that skillful speakers and writers are able so quickly to think of material fitting multiple constraints" (p. 349). They considered the possibility that this could involve spreading activation within a semantic network but rejected this because of its lack of contextual sensitivity. Instead, they suggested that this might be accomplished by heuristic search, in which the rhetorical problem is progressively redefined until it "provides cues that activate appropriate nodes in memory" (p. 349). Flower and Hayes (1984) made a similar suggestion when they claimed that "*abstract, conceptual representations of knowledge are instantiated in prose not by a kind of automatic translation, but by an active rhetorical decision process*" (p. 154).

In other words, the models share a reliance on a theory of knowledge representation as consisting of fixed internal representations and on the assumption that adapting these to the external context involves goal-directed problem solving. As such, they were a classic example of the symbolic approach to cognition inspired by Newell and Simon's work on human problem solving (Newell, 1990; Newell & Simon, 1972) in which knowledge was assumed to be represented in the form of structured networks of symbols and processing information involved the goal-directed retrieval and manipulation of the symbols to create new representations.

WRITING FROM A DUAL-PROCESS PERSPECTIVE

The dual-process model that we present here draws on connectionist principles of information processing (Rogers & McClelland, 2014; Rumelhart et al., 1986) to provide a solution to the problem posed by Bereiter and

Scardamalia. This leads to a reconceptualization of the input to the writing process as it is conceived in Hayes's (2012) model. Content generation in writing is treated as an interaction between an implicitly controlled knowledge-constituting process and an explicitly controlled problem-solving process rather than as a matter of retrieving ideas from long-term memory. Furthermore, the different organizing principles of these two processes leads to a fundamental conflict in writing, different in form to the cognitive overload invoked by classical models of writing.

Knowledge Representation as Parallel Distributed Processing

To illustrate the principles involved, and how they differ from those involved in the symbolic paradigm, consider the contrasting approaches taken by Collins and Quillian (1969) and McClelland and Rogers (2003). Figure 2 shows the different kinds of networks they used to represent propositional information in semantic memory.

In the Collins and Quillian (1969) network, concepts are represented as individual nodes (symbols) linked to their attributes by labeled relations to form propositions about the concepts. The hierarchical organization of the concepts is explicitly represented by links within the network. Retrieval of information takes place by spreading activation through the network. For example, to verify a proposition about whether robins can fly, activation spreads from the "robin" node up to the "bird" node and then to the "fly" attribute of "bird." In sum, concepts and their organization are explicitly represented in the network and information is accessed by serial search.

The network shown on the right was designed by McClelland and Rogers (2003) to represent the same set of propositions according to parallel distributed processing (PDP) principles. This network has two sets of inputs, corresponding to the concepts at the bottom of the hierarchy in Collins and Quillian's network (labeled "Item" in Figure 2) and the set of possible relations between them (labeled "Relation"). Information is processed by passing activation in parallel through two layers of units—a set of representation units forming a distributed representation of the concepts and a set of hidden units combining the concept and relation information—out to a set of output units corresponding to all possible completions of propositions true of the concepts. In combination, the two sets of input units and the output units represent all the concepts and relations encoded in the original Collins and Quillian (1969) network, and once trained, the PDP network can combine these by passing activation forward through the two layers of internal units to the output units. For example, on being presented with "canary" and "can" at the input units, the network produces "grow," "move," "fly," and "sing" on the output units.

The PDP network can store and reproduce the same information as the Collins and Quillian (1969) symbolic network. It does so, however, in a very different way, characterized by two features. First, concepts are not represented by fixed, individual units within the network but rather as fleeting patterns of activation distributed across the layer of representation units, which disappear once processing is complete. Propositions are *synthesized* according to the strengths of the connections between units and are revealed in the output from the network, rather than being retrieved from memory.

Second, the same set of units and connections is used to produce responses to all the different inputs. Thus, the network's knowledge is represented by the strength of the connections between units, and these *fixed* connections are responsible for producing the full range of propositions encoded by the network. In learning to represent these propositions, the network must find a single set of connection strengths consistent with the production of all the different propositions. The consequence is that the hierarchical relationships between the propositions are reflected implicitly in the similarity between the patterns of activation taken up by the representation units rather than as explicit links between symbolically represented categories.

Using cluster analysis of the patterns of activation formed across the representation units during the synthesis of different propositions, McClelland and Rogers (2003) showed that these patterns formed a hierarchical organization identical to the structure explicitly represented in Collins and Quillian's (1969) network. Furthermore, analysis of the changing patterns of activation produced as the network learned showed the same pattern of gradual differentiation as is observed in children's development (see Mandler, 2000, for a review). Early in training, the network distinguished between animals and plants but created similar representations for the items within each category and did not distinguish between trees and flowers or between birds and fish. As the network was exposed to more training examples, it developed distinct representations for these subcategories but still treated individual items within each subcategory alike. Finally, when training was complete, clearly distinct representations were produced for individual items as well. The result was an implicit hierarchy in which individual items within a subcategory had more similar representations to one another than to items from other subcategories, and items within global categories such as animals and plants had more similar representations to one another than to items from the other global category.

In sum, connectionist networks represent knowledge implicitly as the fixed set of connection strengths between

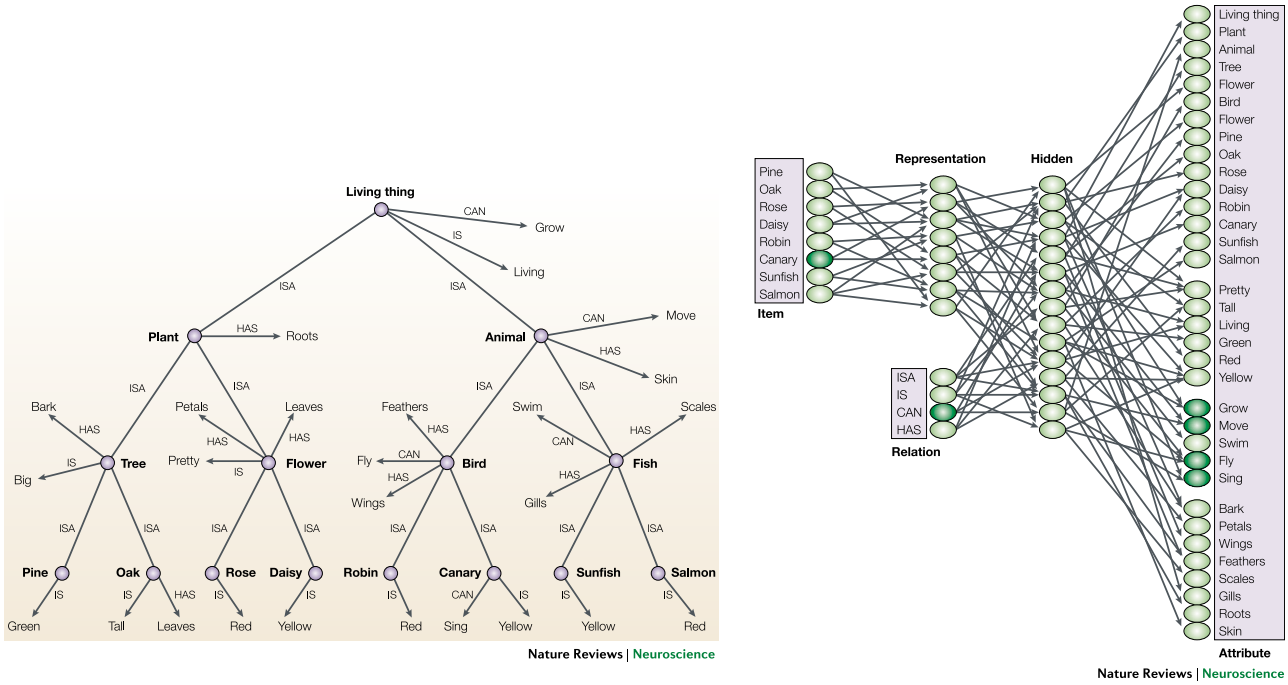

FIGURE 2 Contrasting representations of how propositional knowledge is represented in semantic memory (McClelland & Rogers, 2003). *Note.* The symbolic network proposed by Collins and Quillian (1969) is shown on the left side; the alternative connectionist model proposed by McClelland and Rogers (2003) is shown on the right side. From "The Parallel Distributed Processing Approach to Semantic Cognition" by J. L. McClelland and T. T. Rogers, 2003, *Nature Reviews Neuroscience*, Vol. 4, No. 4, pp. 311 and 314. © Springer Nature. Reproduced by permission of Springer Nature. Permission to reuse must be obtained from the original rightsholder.

units within a distributed architecture, and these connections control the synthesis of individual propositions within different contexts.

Writing as a Knowledge-Constituting Process

Galbraith (1999) used these two basic principles of PDP processing—the synthesis rather than retrieval of content and the implicit rather than explicit organization of knowledge—to provide an account of how dispositionally controlled idea generation could lead to developments of a writer's understanding. Here, we first describe the basic features of this model as it was originally conceived. We then elaborate on how we currently view it and consider how it relates to contemporary theories in cognitive science.

The model has three key features. First, the writer's knowledge is characterized as the writer's *disposition* toward the topic, which is formally defined as the matrix of connection strengths between the units within a constraint satisfaction network. The strengths of these fixed connections are the product of an individual's learning history and reflect the totality of an individual's experience. They are the connection strengths consistent with the production of all the propositions that the individual has encoded and constitute the writer's internally organized, but implicit, understanding of the topic. For the writer to access this knowledge in response to a topic, they must synthesize their ideas by passing activation within the network until an output is revealed as content to be expressed in language.

Second, this initial response to the topic is only a partial "best fit" to the writer's knowledge, restricted both by how the topic is specified and by the limited capacity of the language system to capture all the content in a single utterance. Constraint satisfaction within the network interprets the topic in terms that are compatible with the writer's implicit understanding, but this depends crucially on how the topic is specified. Further, because of the limited capacity of the language system, the formulation of the content is not a matter of direct translation but rather is an attempt to capture a best approximation to the message represented across the units in the writer's disposition.

Third, the initial proposition is fed back through inhibitory connections and provides new input to the disposition. This has the effect of reducing the activation of units corresponding to the writer's initial message and means that, when the same set of initial constraints from the topic are input into the network again, a different pattern of activation is synthesized through constraint satisfaction. This will roughly correspond to the disposition's selection according to its internal constraints from the "remainder" of the content activated by the initial set of external constraints. Galbraith (1999) suggested that one of the consequences of the process was that contradictory

propositions could be synthesized later in the sequence once the content most central to the disposition had been "subtracted" out through inhibitory feedback.

Figure 3 presents a sketch of the overall process as originally conceived. The input to the network consists of the topic and task specification and is shown at the bottom of the diagram. The writer's disposition is shown as the network in the center of the diagram. The pattern of activation formed across the units of this network provides the message to be formulated in language (A in the diagram), which is written down as an utterance (B). Feedback connections (C) from the output then pass inhibitory activation back to the writer's disposition. The resulting new synthesis and formulation of content is labeled D, with the output of further cycles of text production represented at E and F.

As an example of what this involves, consider the following protocol based on a study by Klein (2004) of a group of university students writing informal texts trying to explain how weight and distance affect whether a beam balances. We should stress that, although the example is based on the kinds of material present in Klein's study, it has been invented for the purposes of illustration. In this invented protocol, the writer begins by restating the question in two bursts of language production separated by a pause indicated by ellipses (…): "So what makes … the balance beam tip in one direction?" This corresponds to the topic and task specification. They then produce an initial synthesis of their implicit understanding: "A … greater weight on one side causes it to tip in that direction …". This, however, is only a partial representation of the content of their disposition, so when it is fed back to the disposition, a qualification to the initial statement is synthesized: "… if the weight is placed at the same location." The writer then synthesizes two new statements: "But this depends on where it is placed. … If it was closer to the center of the beam it might not tip the beam," followed by a further synthesis stating a provisional conclusion: "Maybe it depends on both weight and distance?" In summary. a series of statements are synthesized as dispositional responses to the emerging text, resulting in the gradual constitution of the writer's understanding in the text.

The overall claim of the model is that dispositionally controlled content generation is a self-moving process in which the writer's understanding is constituted in the text over a series of utterances. This is not a matter of retrieving a series of pre-stored propositions: Each successive proposition depends on the output of the preceding synthesis and in turn influences the synthesis of its successor. The key feature is that, for the writer's disposition to be fully captured in the text, it must be allowed to guide processing over successive sentences, free from external planning.

Galbraith and Baaijen (2015) described the knowledge-constituting model as a system designed for action, noting that the function of a distributed representation is not just to represent the regularities induced from experience but also to provide resources for acting in the present. The representation of experience as a single set of connections within the writer's disposition means that the structure controlling the synthesis of content is influenced by all the writer's past experiences; the variability of the patterns that can be formed as the output of the network means that the network can then synthesize content appropriate to novel contexts. This emphasis on language production as a form of action is shared by current models of language production (e.g., Pickering & Garrod, 2013). We would also emphasize here the speculative nature of the propositions formed as the linguistic output of the writer's disposition: Each utterance is an attempt to capture the interpretation produced by the disposition; successive utterances represent the disposition's response to this initial hypothesis. The disposition is, in effect, constituting its reasoning about the topic in the text. Finally, Galbraith (1999) focused on the need for the knowledge-constituting process to be allowed to unfold free from interruption by external input from a predetermined plan. We would add here that the extent of the knowledge-constituting process depends not just on external control but also on the scope of the content that it is synthesizing. This is determined by how the topic and task specifications are defined by the writer.

The general principles of this model are consistent with current research. Connectionist models of semantic memory (e.g. Rogers & McClelland, 2004) have become increasingly influential in the field, and these have been accompanied by the development of distributional models that specify mechanisms for constructing semantic representations from text corpora. These originated with the work of Landauer and Dumais (1997) and have since been developed in increasingly sophisticated forms (Jones, Willits, & Dennis, 2015). We see the *disposition* component of the model as equivalent to the high-dimensional semantic space constructed by these models. The broader idea that the knowledge-constituting process involves the gradual articulation of understanding over a sequence of utterances, and that this is driven by feedback from preceding utterances, is echoed by recent developments in cognitive neuroscience. These involve using Bayesian statistical models to model the process by which hypotheses, represented as generative models, interact with perceptual evidence, and then examining how these can be implemented by hierarchically organized, bidirectionally connected, cortical networks (Clark, 2013; Eliasmith, 2007). Action is conceived in such approaches as an error minimization process, in which internal feedback from anticipated perceptions drives the sequence of

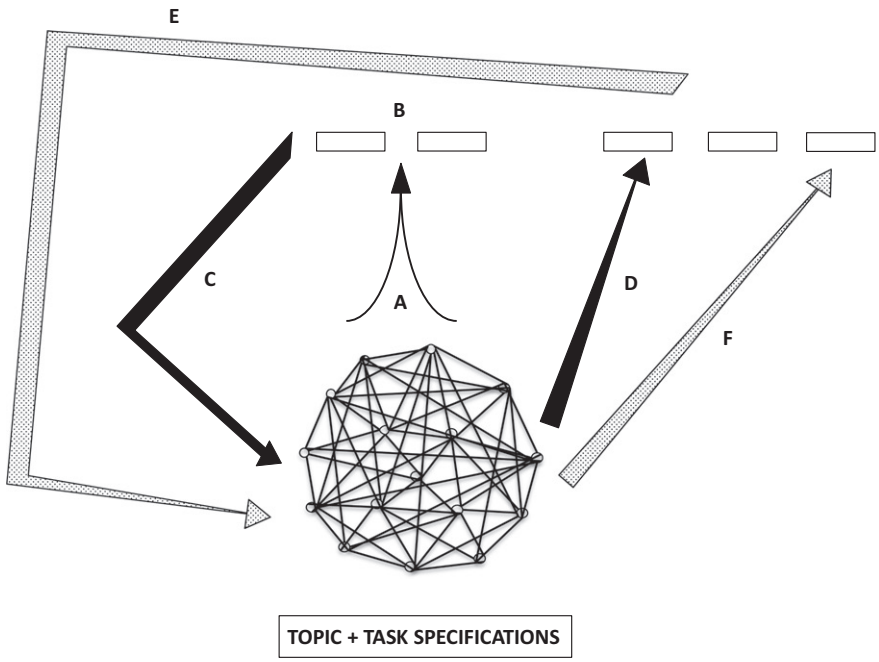

FIGURE 3 Sketch of the knowledge-constituting process. *Note.* Input (Topic and Task specifications) is passed through the writer's disposition (network in the center) and produces language output (A), which is written down in language chunks (B). This output is fed back into the network (C) and with inhibitory feedback leads to further new language production (D). This cycle is repeated (E and F) until the written text captures the writer's understanding. From "Writing as a Knowledge-Constituting Process" by D. Galbraith, in *Knowing What to Write: Conceptual Processes in Text Production*, edited by M. Torrance and D. Galbraith, 1999, Amsterdam, The Netherlands: Amsterdam University Press, p. 142. © David Galbraith. Reproduced by permission of David Galbraith. Permission to reuse must be obtained from the rightsholder.

actions (Friston et al., 2015). This has resemblances to the way in which successive utterances are generated through feedback to the writer's disposition in the knowledge-constituting process. There is a long way to go in developing models that integrate action with the language production system, and the result is likely to differ significantly in detail to the model that we have described here. However, these models of cortical function are consistent with the feedback component of the knowledge-constituting model.

Complementary Learning Systems

Galbraith (1999, 2009) focused on characterizing the nature of the knowledge-constituting process. This was not intended to replace the classical models' accounts. Instead, he suggested that the explicit problem-solving processes described by classical models consisted of operations carried out on ideas retrieved from episodic memory and manipulated in working memory to satisfy rhetorical goals. Little was said, however, about the nature of the content represented in episodic memory—particularly, why it was different to the way that content was represented in semantic memory—or about how the two sets of processes interacted with each other. Here, we first elaborate on the distinction between episodic and semantic memory as it is conceived by complementary learning systems (CLS) theory, and then describe how this relates to the dual-process model.

CLS theory (Kumaran, Hassabis, & McClelland, 2016; McClelland, McNaughton, & O'Reilly, 1995; O'Reilly, Bhattacharyya, Howard, & Ketz, 2014) postulates two memory systems: a semantic system, located in the neocortex and characterized by O'Reilly et al. (2014) "as a distributed, overlapping system for gradually integrating across episodes to extract latent semantic structure" (p. 1229), and an episodic system, located in the hippocampus and characterized "as a sparse, pattern-separated system for rapidly learning episodic memories" (p. 1229). For our purposes, these systems have two key features. First, the semantic system that underlies the writer's disposition is a slow learning system: It does not change during a writing episode. By contrast, the episodic system is capable of fast, single-shot learning. It is the episodic system, therefore, that registers novel output; the semantic system may respond to novel output through feedback, but this influences the sequence the output takes rather than the content that is stored within semantic memory. Second, the sparse nature of the representation in episodic memory means that content can be retrieved as stable, individual ideas and made available for reflection.

This core distinction between two distinct forms of representation has proved capable of accounting for a wide range of neuropsychological and behavioral data

(O'Reilly et al., 2014). Particularly relevant in the present context is the suggestion by Winocur, Moscovitch, and Bontempi (2010) that

> there is a dynamic interplay between the two types of memory such that one or the other may be dominant depending on their relative strength and the circumstances that elicit them at retrieval. As a result, retention and retrieval are continually evolving processes in which the memories can interact and influence each other. (p. 2340)

Dual-Process Model of Writing

Dual-process models have become increasingly prevalent in psychology to account for phenomena in a wide variety of domains. They typically involve a contrast between two systems, often called *System 1* and *System 2*, with processing in System 1 characterized variously as fast, effortless, automatic, nonconscious, and undemanding of working memory, and processing in System 2 characterized as slow, effortful, controlled, conscious, and demanding of working memory (Evans, 2008; Evans & Frankish, 2009). Smith and DeCoster (2000) have argued that the distinctions between the operating principles of the episodic and semantic memory systems underlie many of the characteristics described by different dual-process models and suggested that they provide a means of integrating the theories conceptually. The characteristics of specific theories, however, vary widely in their properties. The model that we present here resembles most strongly the distinction between *intuitive* and *reflective* processes that Mercier and Sperber (2009) made in their discussion of dual-process accounts of reasoning, particularly their claim that "the main function of reflective inference is to produce and evaluate arguments occurring in interpersonal communication (rather than to help individual ratiocination)" (p. 151). Note, though, that the knowledge-constituting process that we have described is very different in form to the modular architecture that Mercier and Sperber invoke to account for intuitive processing.

The model focuses on the contrast between the implicitly organized nature of the knowledge-constituting process and the explicitly organized nature of the knowledge-transforming process. Galbraith (2009) previously characterized the two processes as a distinction between a knowledge-constituting system and a knowledge-retrieval system, emphasizing the distinction between the representations on which the two processes operate. Galbraith and Baaijen (2015) characterized them in terms of their functions as a system designed for *action*, enabling the writer to use the totality of their learning history to synthesize a response to a novel context, and as a system designed for *reflection*, enabling the writer to consciously survey and modify their knowledge. In the following summary, although both these characterizations still apply, we refer to them as the knowledge-constituting process and the knowledge-transforming process.

The Knowledge-Constituting Process

The essential feature of the knowledge-constituting process is that the disposition corresponding to the writer's understanding is not an explicitly retrievable body of knowledge but is instead a structure that guides the synthesis of content. This means that the generation of content is intrinsically a process of discovery: The knowledge implicit in the connections between units is realized as explicit content only once it has been synthesized as text. The knowledge-constituting process is assumed to operate best when writers synthesize their thought in explicit, connected propositions and when successive propositions are produced as dispositional responses to preceding text. The extent to which this leads to a change in the writer's explicit knowledge depends on whether the content that it produces corresponds to existing content in episodic memory. When it does, no development of knowledge will occur; when it does not, the writer will experience a development in their understanding. Finally, because the structure of the text is dispositionally determined, there will be no necessary relationship with the rhetorical quality of the text.

The Knowledge-Transforming Process

The knowledge-transforming process involves the retrieval of explicit content stored in episodic memory, which may be evaluated and manipulated in working memory to satisfy rhetorical goals. This process operates best under the conditions assumed by classical models of writing. It requires ideas to be represented in a fixed and abbreviated form (e.g., as notes) so that the limited capacity working memory system can focus its resources on evaluating the extent to which they satisfy rhetorical goals and their potential contribution to the overall structure of the text. Knowledge-telling occurs when the writer simply retrieves content from memory without considering how to adapt it to rhetorical constraints, whereas knowledge-transforming involves a more strategic search and evaluation of content to satisfy rhetorical goals. Although the knowledge-transforming process does not lead to the formulation of new content, the reorganization of ideas to satisfy rhetorical goals contributes to the development of the writer's knowledge by creating a more coherent object in memory. Furthermore, because the process is directed toward rhetorical goals, it is related to better quality text.

The Two Processes in Combination

The two processes are both necessary for effective writing and, in principle, they have complementary functions. The knowledge-transforming process ensures that content is coherently organized in relation to rhetorical goals and, when content is not explicitly available in episodic memory, can set this as a goal for the knowledge-constituting process. The knowledge-constituting process is required to provide content reflecting the writer's understanding, but this then needs to be explicitly organized to satisfy rhetorical goals. However, because of the contrasting principles under which the two systems operate, there is a potential conflict between them. Dispositionally generated content, which is necessary to constitute the writer's understanding, may disrupt the rhetorical organization of the text; explicit organization to maintain rhetorical goals may prevent the writer's understanding from being fully constituted in the text. Control processes in writing, therefore, are not just about managing the resource demands of different cognitive processes but are about reconciling the demands of these conflicting goals. Successfully managing this conflict enables the writer to create a coherent knowledge object, which satisfies rhetorical goals but at the same time fully captures the writer's implicit understanding of the topic.

As an example of the way in which these processes interact, consider the way in which one of the participants in our research gradually developed a conclusion to her argument during writing and how the text was then reorganized to incorporate this conclusion. The participant in question was discussing the issue of whether our dependence on computers and the Internet was a good development. Having presented some expository material about the development of the Internet over the last decade and then providing some examples of positive effects and negative effects, she set about formulating a conclusion (explicit rhetorical planning or goal setting). But this did not lead to a direct statement of a conclusion following an extended period of thought. Rather, the conclusion was gradually developed over several paragraphs. She first reiterated the positive and negative effects in summary form (synthesizing previous written text). She then wrote:

> But does this mean that we should ban all internet use? … No, definitely not … What matters—and this is actually always the case—is that you can make good use of something and even enjoy it so long as you do it in moderation.

She then recalled an advertising slogan used by the alcohol industry: "Enjoy but drink in moderation" (retrieval from episodic memory) and wrote:

> Why can't we apply that to other things in life? Health insurance agencies, enjoy but don't just put your forms on the Internet where the elderly or people without a computer can't access them. Enjoy online games but set a limit on the playtime per person per day. Above all, enjoy the internet but in moderation.

This final phrase was then cut and pasted as the title of the whole piece. She then deleted all the paragraphs through which she had developed this and wrote a brief concluding paragraph. According to the dual-process model, this reflects an initial setting of goals through explicit problem solving followed by a series of dispositionally guided syntheses trying to capture her thought, interspersed with retrieval of information from episodic memory. She finally discovered what she is trying to say, which forms a new global organization for the text, but the text that led to this is deleted and a new, briefer, and better presented conclusion is formulated. Thus, dispositionally guided text production is required to arrive at the conclusion, but because this conflicts with the requirements of rhetorical form, it is ultimately deleted. The two processes are required in combination for the writer to both constitute their understanding and present this in a rhetorically effective form.

EVIDENCE FOR THE DUAL-PROCESS MODEL

In his review of research on the cognitive processes involved in writing-to-learn, Klein (1999) identified four hypotheses about the processes involved: (a) the spontaneous generation of knowledge "at the point of utterance," (b) reviewing and revision of ideas externalized in the text, (c) the use of the structures associated with different text genres to organize ideas in the text, and (d) the solving of content problems to satisfy rhetorical goals. In the model presented in this article, the knowledge-constituting process is intended as an account of the cognitive bases for "shaping at the point of utterance," and the dual-process model proposes that the remaining three processes should be treated as operations on the objects synthesized by the knowledge-constituting process or retrieved from episodic memory. It therefore proposes that all four of the processes identified by Klein (1999) can be combined in a single model.

In previous sections, we have discussed the evidence for the main components of the model from research and theory in cognitive science more generally. We have also suggested how this can be incorporated within cognitive models of writing, using Hayes (2012) as an example. Our fundamental argument is that research on writing needs to take greater account of these developments within cognitive science more generally. In the current section, we turn to research specifically on writing and discuss the evidence it provides for the claims of the dual-process model.

A central claim of the model is that spontaneous writing is an active knowledge-constituting process leading to developments of the writer's understanding. Some evidence of this comes from a study by Klein (2004) of a group of university students who were asked to think aloud while they wrote informal texts trying to explain elementary science phenomena. Analysis of the protocols and texts produced by students who made explanatory gains compared to those who did not indicated that three processes were important: *automatic retrieval*, which involved the spontaneous generation and translation of ideas; *controlled retrieval*, which involved intentional search of long-term memory combined with deliberate scrutiny of the results of the experimental demonstration the students had witnessed; and *problem solving*, which involved goal setting and the metacognitive operations associated with the knowledge-transforming model. In addition, he remarked that aspects of automatic retrieval resembled the knowledge-constituting process, noting that a substantial minority of the students who made explanatory gains wrote an initial explanation then immediately rejected it, without any intervening explicit reasoning: "Writing the initial explanation triggered its rejection in a manner consistent with the knowledge-constituting model" (Klein, 2004, p. 219). Overall, then, this study indicated that the development of understanding in writing was multiply determined by a combination of explicit problem solving, directed search of long-term memory, and more spontaneous text production processes.

This, of course, is circumstantial evidence. To pin this down further, we turn first to research on idea generation and then to research that assessed more directly the processes involved and how they relate to the development of understanding and the quality of the text.

Research on Idea Generation

Galbraith (1992) investigated the effect of self-monitoring and mode of writing on the development of new ideas and writers' subjective ratings of their understanding of the topic. This suggested a double dissociation between self-monitoring and mode of writing in the conditions under which the two groups developed new ideas. High self-monitors, whose writing was assumed to be directed toward rhetorical goals (Klein, Snyder, & Livingston, 2004; Snyder, 1987), developed more new ideas when they were asked to make notes in preparation for an essay than when they were asked to write a full text. Furthermore, although they reported increases in understanding after making notes, these were unrelated to how many new ideas they had developed. By contrast, low self-monitors, whose writing was assumed to be directed toward dispositional goals, developed few new ideas after making notes but a high number of new ideas after writing full text. Furthermore, the number of new ideas they produced was strongly correlated with the extent to which they reported increases in understanding.

According to the dual-process model, this pattern of results reflects the fact that, when making notes, content is primarily retrieved from episodic memory, and hence the extent to which new content is introduced depends on the extent to which content is retrieved and manipulated to satisfy rhetorical goals (high self-monitors). Because this is assumed to take place in working memory, the effect is reduced when writers produce full text, and because increases in understanding under these conditions are assumed to reflect changes in organization, there is no relation with the number of new ideas. By contrast, when producing full text, new content depends on the extent to which ideas are dispositionally synthesized (low self-monitors) and is reduced by the imposition of rhetorical goals (high self-monitors). Furthermore, because these ideas are dispositionally synthesized, there is a direct relationship between the number of new ideas produced and the development of the writer's understanding.

Clearly, this goes some way beyond the data. Apart from anything else, the fact that self-monitoring is an individual difference variable means that other factors cannot be ruled out–for example low and high self-monitors may differ in how they assess their understanding. Furthermore, there is no direct evidence of the goals toward which writers were directing their writing. Nevertheless, this experiment does indicate that the two processes involved in developing understanding can be disentangled by focusing separately on planning processes free from full text production and on dispositionally guided text production.

The Knowledge-Transforming Component

It is generally agreed that outlining in preparation for writing an essay helps improve the quality of the text (Kellogg, 1994). Our focus here is not so much on this issue but rather on how operations on ideas, when they are represented in abbreviated form to support manipulation of ideas in working memory, affects the writer's understanding and how this in turn relates to the quality of the text. According to the dual-process model, the benefits of outlining depend not just on being able to generate ideas free from the demands of full text production but crucially on the extent to which ideas are explicitly organized to satisfy rhetorical goals.

Kellogg (1990) found clear evidence to support this in an experiment with university students in which three forms of planning were compared with a control condition where no prewriting took place. Simply jotting down ideas in an unordered way made no difference to the quality of the final text compared to the control condition, listing ideas in the order required for the final text produced

a significant improvement compared to control, and constructing a hierarchical outline of the text to be written produced the highest quality of all. In a later study with university students, Rau and Sebrechts (1996) compared a no prewriting control condition with conditions in which students were asked to think aloud while either thinking about the composition or constructing a written outline of the text. They found that outlining reduced the amount of revision carried out during writing compared to the two other conditions and crucially that, whereas students in the thinking condition just generated content (90% of the protocol segments), those in the outlining condition engaged predominantly in rhetorical planning (70% of the protocol segments compared to only 30% devoted to content generation). Furthermore, it was the amount of rhetorical planning that accounted for the improved quality of the texts produced after outlining.

These experiments suggest, then, that operations on ideas represented in abbreviated form affect subsequent text quality to the extent that they are directed toward rhetorical goals. But to what extent does this involve transforming ideas, and does it lead to a development of writer's understanding of the topic? Two experiments by Galbraith and his colleagues (Galbraith, Ford, Walker, & Ford, 2005; Galbraith, Hallam, Olive, & Le Bigot, 2009), using a similar method, suggest a partial answer to these questions. Writing was divided into three phases: In Phase 1, writers generated a list of ideas about a topic; in Phase 2, they created an organized outline of the text; and in Phase 3, they wrote the text itself. During the outlining phase, they were asked to carry out secondary tasks designed to load on different components of working memory. In both cases, the aim was to assess how ideas were transformed between Phases 1 and 2 and how this related to the quality of the text produced in Phase 3. The two studies showed that the quality of the final text depended on the extent to which new ideas were introduced during outlining (Phase 2) and on the extent to which the outline was organized in terms of rhetorical goals. Furthermore, both showed that this effect was removed when outlining had to be carried out at the same time as a secondary task designed to load on the spatial component of working memory but not by tasks loading on other components of working memory. In addition, Galbraith, Ford, Walker, and Ford (2005) found that university students carried out more extensive reorganization of content and produced better quality text than younger, 16-year old students. Galbraith et al. (2009) found, further, using latent semantic analysis (Landauer & Dumais, 1997) to compare the content of the initial lists with the content of the outline, that high self-monitors changed content more during outlining than low self-monitors, consistent with the findings for the note-making condition in Galbraith's (1992) study. Of interest, however, there were no differences in the extent to which low and high self-monitors introduced new ideas or rhetorical headings during outlining, or in the quality of the final text. This suggests that it is not the amount of content change that is important as the extent to which content is differentiated into separate ideas organized in terms of rhetorical goals (later confirmed in a reanalysis by Galbraith & Baaijen, 2015) and, further, that although low self-monitors may change their ideas less according to context (Klein et al., 2004), they are able to construct rhetorically organized outlines when explicitly instructed to do so, with the same effects on text quality as for high self-monitors.

Although these studies suggested that organization and rhetorical goals are associated with improvements in the quality of the text produced following outlining, none of them assessed effects on the writers' subjective understanding of the topic. Furthermore, because they left the writers free to write what they wanted about the topic, they do not provide any direct evidence of whether the generation of ideas involved retrieval from episodic memory. Two more recent studies provided more direct evidence that organization of ideas in terms of rhetorical goals is also associated with developments of the writer's understanding.

The first of these (Klein, Haug, & Arcon, 2017) investigated the effect of providing goal prompts for fifth to seventh graders in a writing from sources task about the classification of vertebrates. The students were first given a multiple-choice test about the classification of vertebrates and then were provided with grade-appropriate material that enabled them to infer, but did not directly state, the solution to a classification problem. With the source materials available, students were then asked to write a text persuading a reader of how a particular mammal should be classified. They did so under one of three conditions, varying in the type of goal prompts they contained: (a) content prompts—potentially relevant attributes they could consider during writing; (b) rhetorical prompts—cues prompting them to provide reasons for their claim, to produce a potential alternative claim and its reasons, and to provide a counterargument to the alternative claim; and (c) a control condition, in which students were just given the general persuasive instructions for the task. Each condition included two training sessions followed by a transfer activity in which students carried out the persuasive writing task without prompts. For present purposes, the key finding was that the rhetorical prompt condition led to the production of better quality text and that this was also associated with improved performance on a posttest of classification ability. By contrast, although the content prompt condition also led to improved classification ability, it was not associated with improvements in text quality. Overall, although this study does not directly involve planning in note-form, the

results support the claim that writing organized in terms of rhetorical goals is associated with both the development of the writer's understanding and the production of better quality text.

The second study was carried out by Arnold et al. (2017). They asked 100 undergraduate students to study texts on technical aspects of astronomy and measured their performance, 2 days later, on a range of measures of their understanding of the texts. They compared two experimental conditions—(a) an essay condition, in which, after the text had been removed, students were asked to write a descriptive essay about the topic of the texts, and (b) a recall condition, in which students were asked to recall everything they could from the passage after reading them—with two control conditions, in which students either highlighted passages in the texts or made notes on them as if learning for a class. They also collected measures of individual differences in verbal working memory capacity, writing ability, and structure-building ability (a measure of the ability to construct organized mental representations of texts and events (Callender & McDaniel, 2007). For present purposes, the key features of this study are that it included an explicit memory-retrieval task and that it tested the effects of the tasks on writer's understanding of the text. The results showed that students in the two experimental conditions had a better understanding of the texts when tested 2 days later than students in the two control conditions but that this depended on the students having a relatively high structure-building ability. Furthermore, analysis of the extent to which the essays and the recall texts "consisted of connected and well-organized sentences that read like an essay" (p. 123) showed that performance in the recall condition depended entirely on the extent to which the texts were essay-like in form: Those structured like an essay were associated with equivalent levels of understanding to the essay condition; those that consisted simply of a listing of content from the passages they had read had no beneficial effect on learning.

These studies provide consistent evidence, therefore, in support of the knowledge-transforming model of planning: Text quality was related to the generation of new ideas organized in terms of rhetorical goals in both experiments. Taken together, they are consistent with the dual-process model's contention that effective planning involves the retrieval of ideas from long-term memory and their reorganization in (spatial) working memory to satisfy rhetorical goals.

The Knowledge-Constituting Component

The properties of the knowledge-constituting component of writing have been less researched, and this research is primarily based on the research of Galbraith and his colleagues. In two experiments using similar methods to Galbraith (1992), Galbraith (1999; Galbraith, Torrance, & Hallam, 2006) compared low and high self-monitors writing full text after different forms of pre-planning and assessed the effects on the generation of new ideas and subjective ratings of understanding and organization. The key distinction was between *synthetic* planning—writers had to sum up their ideas in a single sentence before writing the text—and *outline* planning—writers had to construct an outline of the text to be written before writing. Galbraith (1999) confirmed the earlier finding of Galbraith (1992): Low self-monitors produced more new ideas after writing full text than high self-monitors. But, in addition, this difference was at a maximum when writing was synthetically planned, and it was only in this condition that the number of new ideas was positively correlated with increased understanding. Galbraith et al. (2006) confirmed the contrasting effect of synthetic planning on the generation of new ideas by low and high self-monitors but also found that the ideas produced after low self-monitors' synthetically planned texts were more coherently interrelated than those produced after high self-monitors' outline planned texts.

Taken together with Galbraith's (1992) findings, these studies provide consistent evidence for an association between a distinctive form of dispositionally guided (low self-monitors) text production and the development of writers' understanding. Furthermore, this appears to be different to the processes associated with the development of understanding when writers are asked to generate ideas in note-form. There are, however, important limitations to this conclusion. First, there is the problem of the potential confounding factors that could be associated with the individual difference variable of self-monitoring. Second, there is no direct evidence about the processes involved. Finally, none of these studies has assessed how this form of discovery is associated with text quality. These limitations have been addressed in a recent study by Baaijen and Galbraith (2018).

Baaijen and Galbraith (2018) used principal components analysis of keystroke logs to identify two components of the writing process. The first of these reflected the extent to which the global structure of the text was reorganized during writing. At one extreme, sentences were produced in a linear fashion; at the other extreme, writers moved back and forth in the text, adding and deleting text as they wrote. The second dimension measured variations in how individual sentences were produced. At one extreme, sentences were produced in a controlled way, with relatively longer pauses between sentences followed by clean language production and little revision; at the other extreme, sentences were produced more spontaneously, with relatively brief pauses between sentences followed by more extensive revision at the point

of inscription. Baaijen and Galbraith then assessed the relationships between these writing processes, changes in writers' subjective understanding and text quality. As in the earlier research on idea generation, low and high self-monitors were asked to write texts following either synthetic or outline planning. This study had two important findings.

First, the two process variables made independent, and additive, contributions to the development of the writers' understanding. Increases in understanding were associated with greater revision of global structure during writing and with synthetically planned, spontaneous sentence production. Important to note, these relationships were independent of self-monitoring, ruling out this as a potential confounding factor. Furthermore, the pattern of relationships between the sentence production component and increased understanding had interesting correspondences with contrasting hypotheses about discovery through writing. Figure 4 shows the relationships they found between the sentence production variable and increases in understanding as a function of different types of planning (Baaijen & Galbraith, 2018, p. 14).

As can be seen in the figure, when writing was outline planned, changes in understanding were relatively small and tended to depend on how controlled sentence production was. Baaijen and Galbraith (2018) argued that this represented a contrast between knowledge telling, in which ideas were directly retrieved from the predetermined outline, and knowledge-transforming, in which ideas were modified during local planning to ensure compatibility with the outline. This pattern also corresponds with the distinction made by Klein (2004) between automatic and controlled retrieval of ideas during writing. By contrast, when writing was synthetically planned, increases in understanding depended on how spontaneous sentence production was and were reduced the more controlled it was. According to the dual-process model, this is because, in the absence of a plan specifying the order of ideas to be produced, the writer synthesizes their ideas according to dispositional constraints and gradually constitutes their ideas in the text. Overall, then, these results indicate that discovery is a consequence of two independent processes, one corresponding to the reorganization of ideas during writing and the other corresponding to dispositionally guided text production.

Second, the two components had different relationships with text quality. Spontaneous text production was, as predicted by the dual-process model, negatively related to text quality. Reorganization of the text was generally positively correlated with text quality; however, this varied depending on type of planning and on the extent to which writers developed their understanding. In the outline condition, text quality was negatively correlated with the development of understanding; it was only when

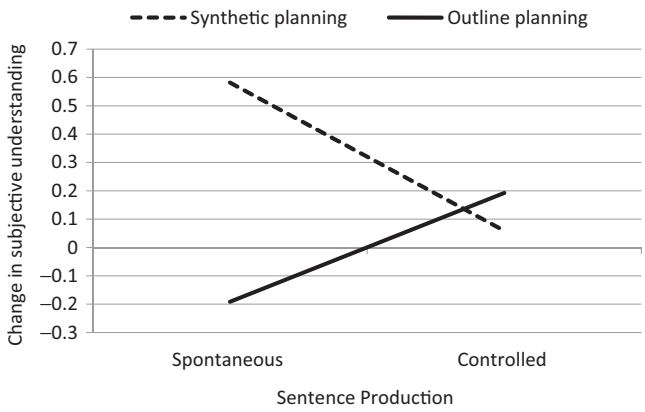

FIGURE 4 Relationship between sentence production and change in understanding as a function of different types of planning. From "Discovery Through Writing: Relationships With Writing Processes and Text Quality" by V. M. Baaijen and D. Galbraith, 2018, *Cognition and Instruction*, advance online publication, p. 14. © Veerle M. Baaijen and David Galbraith. Reproduced by permission of Veerle M. Baaijen and David Galbraith. Permission to reuse must be obtained from the rightsholder.

reorganization was restricted to the text, without any effect on the writers' understanding, that global reorganization was associated with higher quality text. By contrast, in the synthetic planning condition, there was a positive relationship between text quality and the development of understanding.

Taken together, these studies provide evidence that a distinctive, dispositionally guided form of text production is associated with the development of the writer's understanding but not with text quality. This is consistent with the dual-process model's assumption that this form of text production is driven by the writer's implicit disposition toward the topic and that it is directed toward the constitution of their thought rather than toward rhetorical goals. By contrast, the positive relationship of global reorganization of the text with both the development of understanding and text quality is consistent with the dual-process model's assumption that this process is driven by rhetorical goals. Note, however, that the complex pattern of results for this relationship indicate that the effectiveness of this process depends on how the overall writing process is managed. They also suggest that the relationship between text quality and the development of understanding is not as direct as assumed by the classic cognitive models of writing.

IMPLICATIONS

It has generally been assumed within writing research that expert writing is a knowledge-transforming process involving the joint evolution of the writer's understanding and the quality of the text. However, apart from research

concerned specifically with writing-to-learn, there has been very little research that has directly assessed the development of the writer's understanding during writing. It has just been taken for granted that a "knowledge-transforming" process, in which content is adapted to rhetorical goals, also develops the writer's understanding. We have argued in this article that the development of the writer's understanding actually involves two independent processes, operating according to different principles, and that these have conflicting effects on the quality of the text. We think that the research we discussed in the previous section is consistent with this general claim. The first important implication of this research therefore is that writing research needs to assess not just the quality of the text but also the development of the writer's understanding during writing. To fully understand writing, we need to understand the cognitive processes involved in the creation of content and to be able to track how the writer's understanding takes form in the text as the writer attempts to shape this into a rhetorically effective form.

That said, the evidence is less clear about whether the development of understanding involves a knowledge-constituting process of the form that we have described. The evidence points to there being something different about how ideas are generated during full text production compared to planning, either in advance of writing or in combination with text production. But it remains an open question whether this takes the knowledge-constituting form that we have proposed. Perhaps problem-solving models of writing can account for the evidence in terms of a contrast between local problem-solving operations carried out during text production and more global operations carried out during global planning and revision. This would involve claiming that developments of understanding during both text production and global planning or revision are a consequence of the same kind of processes—hence they are both associated with discovery—but that they have different effects on text quality because of differences in how developments at different levels can be coordinated, particularly when required to combine them while writing a single draft of text. Effects of individual differences could then be attributed to differences in preferences for top-down or bottom-up coordination of processes. Although such post hoc explanations are possible, we think that this is essentially an empirical question, resting fundamentally on the nature of the processes involved in spontaneous text production. We discuss how the knowledge-constituting model's claims about these could be further tested next.

In what follows, we begin by discussing the scope of the dual-process model. To what extent does it apply to younger writers, and how might it develop? Is it a general feature of writing or is it only applicable to specific forms? We then consider how the more detailed features of the knowledge-constituting model could be explored in future research, focusing on how it could be distinguished from alternative problem-solving explanations. We then return to considering development issues, discussing the developmental factors that might influence the development of understanding in writing and the strategies that could be used to enhance this.

Scope of the Dual-Process Model

The evidence for the dual-process model that we discussed in the previous section was largely, though not exclusively, based on research with adults. A natural question is whether the same phenomena can be observed in younger writers. The first point we want to make is that, conceptually, one would expect the knowledge-constituting component of the model to occur earlier in development than the knowledge-transforming process. Given that the features of the knowledge-constituting process as we have described it arise from basic properties of the way that structure is extracted from experience and the limited expressive capacity of language production system, it should in general play a role in developing understanding. By contrast, knowledge-transforming depends on the ability to manipulate material in working memory in pursuit of rhetorical goals, and so will depend not just on increases in working memory capacity but also on explicit knowledge of different rhetorical goals. We would argue, therefore, that knowledge constituting is an intrinsic consequence of language production and that spontaneous writing has been misrepresented as knowledge telling because of the general failure to directly assess its effects on the development of understanding. By contrast, knowledge transforming depends crucially on the development of explicit discursive forms in educational contexts.

The research by Klein and his colleagues on writing-to-learn (Klein, 2000; Klein, Haug, & Arcon, 2017; Klein & Kirkpatrick, 2010) provides consistent evidence that younger writers, ranging from fourth to eighth grade, can use writing to make gains on an objective measure of learning. It has also provided indications that this may involve more spontaneous processes as well as the more deliberate problem-solving processes involved in the knowledge-transforming model. This paradigm provides a framework within which the knowledge-constituting hypothesis could be explicitly tested for younger age groups. This would include a measure of subjective understanding, as well as the more objective measures of learning, and actively manipulate the form of writing, so that it included the form of synthetically planned text production that we have claimed corresponds to the knowledge constituting process.

A second question about the scope of the phenomenon is about the nature of the writing task that is involved.

The tasks used in previous research have varied from writing an argument about a personal opinion (Baaijen & Galbraith, 2018) to writing a descriptive essay about a source text (Arnold et al., 2017). One might argue that knowledge constituting is relevant only for more personal topics and that it is not a component of more academic writing. It is important to establish the generality of the phenomenon not just developmentally but also across different types of writing tasks. The dual-process model again argues that knowledge constituting is a general feature of the writing process and, indeed, that strategies need to be developed to encourage it, particularly in academic contexts, where it is presumed to enable writers to provide a more distinctive interpretation of content. A strong test of this claim would be to establish whether knowledge constituting plays a role even in circumscribed tasks like those used by Arnold et al. (2017), in which university students were tested on their comprehension of a source text after writing a descriptive essay about it. Although Arnold et al. attributed the enhanced comprehension for participants writing essays to the organization of the essays, it is arguable that this could also have been affected by the fact that the essay-like responses were written in explicit connected sentences, a key condition for the knowledge-constituting process. This could be tested explicitly by manipulating the form of text production required for the essays and assessing the effects on writer's subjective understanding as well as on the more objective measure of the comprehension of the text.

Identifying the Processes Involved in the Knowledge-Constituting Process

Despite its centrality in the writing process, idea generation has been the subject of relatively little research (Berninger et al., 2009; Crossley, Muldner, & McNamara, 2016). The research we described in the previous section represents one approach to doing this, relying essentially on assessing changes in the ideas and ratings of subjective understanding produced before and after writing. However, future research needs to move beyond this to investigate how ideas are generated during writing itself, rather than, or as well as, changes to ideas listed before and after writing. There have been some preliminary attempts to do this that could be built on in future research. Crossley et al. (2016) used an array of computational text analysis tools combined with human ratings to assess the relationships between the ideas generated in a large corpus of texts and both linguistic features of the text and the overall quality of the text. They found that the overall quality of the text was linked to the number of ideas expressed in the text and the degree to which they were elaborated; these, in turn, were linked to the use of more complex language and more globally, but less locally, cohesive text. It is tempting to see these features as analogous to the two components of the dual-process model: greater elaboration of ideas as evidence of the implicitly controlled knowledge-constituting process, and greater global coherence as evidence of the explicit global revision process. To test this, however, it would be necessary to combine the kind of text analysis that Crossley et al. (2016) used with keystroke logging, to capture the processes associated with the creation of ideas and their linguistic features, and subjective ratings of the writer's understanding, to capture the extent to which different components were related to the constitution of the writer's understanding. In addition, it would be important to assess how the idea generation measures and linguistic features varied as a function of different types of planning—outline and synthetic planning in particular—and as a function of individual differences in variables such as self-monitoring and writing beliefs. The overall aim of such research would be to assess how processes were related both to external criteria and to the internal dynamics of the idea generation process.

At its broadest, the dual-process model is a general claim about the importance of the development of the writer's implicit understanding during text production, and we believe that the evidence we have reviewed warrants a greater emphasis on this in future research. However, in its strongest form, the dual-process model makes a specific claim about how this takes place. Research to date has identified where this process looks like it might be taking place but has not established whether the processes involved are of the form specified by the model of the knowledge-constituting process (Galbraith, 1999). Baaijen and Galbraith's (2018) findings suggest that it depends on text production being synthetically planned and that it is associated with briefer pauses between sentences accompanied by more extensive revision at the point of utterance. The key question is whether the process occurring between sentences is of the synthetic form specified in the knowledge-constituting model and whether revision taking place at the point of utterance is a consequence of a dispositional response to the preceding text. This second feature is easier to test. Retrospective protocols could be collected from writers with a view to establishing whether the revision that takes place at the point of utterance is directed toward capturing the writer's implicit understanding more precisely or whether it is designed to improve the rhetorical effectiveness of the text. The first feature is harder to test. One possibility would be to compare the production of sentences following either synthetic planning or outline planning and to identify the relative activity of the neocortical regions that the dual-process model postulates are involved in the synthesis of content and the hippocampal

regions that it proposes are involved in retrieval of content from episodic memory.

Teaching and Development

Development in writing is currently conceived in classical models of writing as a broad movement from knowledge telling to knowledge transforming (Bereiter & Scardamalia, 1987), and the focus of research has been on the importance of automating the transcription process to free up resources for the higher level problem-solving processes required for knowledge transforming (Berninger et al., 2002; Kellogg, 2008) and on developing students' knowledge of the structure (as represented in the goals for writing) of different genres of writing. The dual-process model acknowledges this as an important component of the writing process and recognizes the effectiveness of instruction targeted at these skills and goals (Graham, 2006; Graham et al., 2012). It highlights, however, the relative neglect of the knowledge-constituting process and stresses that the development of the writer's understanding is an equally important component of the writing process, which requires the development of a different set of skills and expertise.

Factors Affecting the Development of Knowledge Constituting

First, the dual-process model provides a different diagnosis for the origins of knowledge telling and places more emphasis on the development of the writer's knowledge as a crucial contributor to the process, in addition to the development of linguistic and transcription skills and knowledge of the goals required for writing in different genres. CLS theory (Kumaran et al., 2016; McClelland et al., 1995) contrasts the rapid learning of individual episodes (or what me might call "ideas" in the context of writing) within the hippocampal system with the slow learning involved in extracting semantic structure represented in neo-cortical systems. This provides a natural explanation for the movement from a simple, knowledge-telling system toward a more complex system. The reason why writing becomes more difficult as writers develop, unlike other forms of expertise (Scardamalia & Bereiter, 1992), is because the semantic system becomes increasingly complex rather than just because students develop more complex goals for their writing. As the semantic system develops, writing is no longer just a matter of retrieving ideas from episodic memory but also depends on the writer's ability to constitute their implicit understanding in the text. This is an important confound in a great deal of developmental research on writing: Differences between age groups may be because of developments in the complexity of the semantic system as well as developments in the complexity of the writer's goals. The dual-process model predicts that, when comparing writing "horizontally" across topics varying in knowledge, writers will not just produce longer texts on topics they know a lot about (knowledge telling) but also show evidence of a more complex knowledge-constituting process and that writers will experience greater developments in their understanding when they write about "high" rather than "low" knowledge topics. In general, the dual-process model suggests a need for research not just on the development of writers' capacity to satisfy external rhetorical constraints but also on the effects of writing on the development of the writer's understanding.

It is not only knowledge that develops in writers; their more general linguistic skills and more basic transcription skills also develop. The dual-process model implies that this is important not just because it enables writers to produce text more automatically, and hence allows them to focus more on other, higher level problem-solving processes, but also because it enables them to constitute their thought more effectively in text. Given that the knowledge-constituting process is assumed to involve alternating synthesizes of content and dispositional responses to the preceding text, an important question is how the writer's linguistic abilities affect their ability to synthesize content moment-by-moment in the text. To what extent does linguistic ability affect how this process unfolds, and does it influence the extent to which a writer relies on the knowledge-retrieval system or the knowledge-synthesizing system? This has been the subject of relatively little research, apart from some early pioneering research by Scardamalia (1981) on children's capacity to combine ideas in writing. It could be investigated further by assessing the effects of sentence-combining instruction, or other forms of grammar instruction, on the extent to which writers experience developments in their understanding as a function of writing.

Drafting Strategies

Perhaps the key implication of the dual-process model arises from the evidence that outline planning suppresses the knowledge-constituting component of the writing process. Most interventions designed to support the development of children's writing assume the basic division between planning, translation, and revision processes described in Hayes and Flower's (1980) original model of writing and focus on developing the writer's skills in each component. They may also include instruction on different possible ways of combining these processes. There is good evidence for the effectiveness of such approaches (Graham, 2006; Graham & Perin, 2007). However, the dual-process model would claim that this only develops the knowledge-transforming process and that in so doing

it prevents the development of the knowledge-constituting process. It suggests two ways in which this could be overcome.

First, it suggests an alternative approach to drafting and revision, based on the goal of gradually developing the writer's understanding over a series of drafts. This would essentially be a matter of organizing the text after a dispositionally guided draft had been produced rather than organizing it in advance of producing a controlled text. This is a strategy known as *reverse outlining*, which is commonly recommended as an alternative to outlining in advance (Elbow, 1973, 1981). Although this has not been the subject of much empirical research with younger writers, there is evidence from questionnaire studies that it can be used effectively by some university students (Torrance, Thomas, & Robinson, 1994, 1999, 2000), from an experimental study that it can be as effective as an advance outlining strategy for university students (Galbraith & Torrance, 2004), and from an intervention study that it can be used effectively by some high school students (Kieft, Rijlaarsdam, & van den Bergh, 2008). Clearly, it would be interesting to test whether it could be used by younger students.

Second, it suggests that it is important to develop students' metacognitive understanding of the functions of different components of the writing process. The origin of preferences for different strategies are not well understood. However, a recent study by Baaijen, Galbraith, and de Glopper (2014), investigating the effects of different writing beliefs on writing performance under synthetic and outline planning conditions, suggested that they may be related to the way that individuals define writing. The Writing Beliefs Scale developed by White and Bruning (2005; see also Sanders-Reio, Alexander, Reio, & Newman, 2014) includes a dimension that distinguishes between high and low transactional beliefs about writing. Writers with high transactional beliefs see writing as a way to deepen their understanding of a topic and are therefore, according to White and Bruning, more emotionally and cognitively engaged in the process of writing than writers with low transactional beliefs, who view writing as a matter of reporting content from authoritative sources. Baaijen et al. (2014) found that writers with low transactional beliefs wrote better when they were able make an outline than when writing was synthetically planned but that they did not develop their understanding through doing so. By contrast, writers with high transactional beliefs wrote equally well regardless of how they planned their texts but developed their understanding only when writing was synthetically planned. These results suggest that effective use of different drafting strategies depends on writers' beliefs about the functions of the writing process. Given that writers presumably develop these beliefs in the early years of learning to write, they suggest that early instruction should focus not just on different strategies for writing but also on developing metacognitive understanding about the functions of the different components of the writing process.

Motivation

Metacognitive understanding of the functions of different components of the writing process is particularly important because of its potential effects on motivation. Being able, and learning how, to develop one's understanding through writing is likely to enhance motivation to write; equally, being unable, or feeling that one is not allowed, to develop one's understanding is likely to reduce motivation to write. There is some indirect evidence in previous research that supports this possibility. White and Bruning (2005) found that writers with high transactional beliefs were more likely to report writing for pleasure, to see themselves as writers, and to view writing as a means of self-expression than low transactional writers. This implies that the development of understanding may play an important mediating role in motivation to write and that, to the extent that writing instruction promotes forms of writing that suppress, or fail to develop, the knowledge-constituting process, it may enhance the quality of the written text, but at the expense of the development of the writer's motivation to write. Future research needs to assess the effects of writing instruction on motivation, as well as on the ability to produce rhetorically well-formed text.

Voice in Writing

Before we conclude, we want to step back from the details that we have been discussing and say a few words about the final result of learning and teaching writing. We have argued that the structure implicit in semantic memory is extracted from the totality of an individual's learning history, including the social contexts in which learning took place. This structure is profoundly socially determined. Once it has been internalized, however, the immediate process by which a writer's understanding is constituted in the text is not a social process. Indeed, it is precisely the monologic nature of writing that allows writers to build their own distinctive organization of content. The writer does not have to replace an absent conversational partner with a surrogate in "rhetorical space." This is still a struggle between the implicit organization responsible for synthesizing thought and the emerging external organization of the text, but in this struggle the writers have the freedom to find their own individual organization of content. It is the distinctive way in which an individual organizes his or her thought that characterizes a writer's *voice.* This has often been cited as a goal

of writing but has been difficult to make tangible. The definition of the writer's disposition as the fixed weights in a constraint satisfaction network, and the account of the way in which, in combination with inhibitory feedback, this controls the synthesis of successive content, provide a way of explaining how a writer can produce text that is both distinctive and internally coherent. Knowledge constituting is a necessary but not sufficient condition for an individual's writing to have voice. It follows also that, to develop *voice* in an individual's writing, one should aim to promote the knowledge-constituting process and the combination of this process with the problem-solving process.

CONCLUSION

Our central claim in this article has been that the writer's understanding has been neglected both theoretically and empirically in writing research. We have attempted to remedy this by providing a theoretical account of how the constitution of the writer's understanding in text can be represented in terms of connectionist principles of information processing and indicating how this can be integrated with current classical models of writing. We have suggested that there is a preliminary empirical basis for the characteristics of the dual-process model but acknowledge that this needs to be developed by further research, indicating directions that this could take. Even if the processes involved can be accommodated conceptually within classical problem-solving models of writing, we suggest that greater emphasis needs to be given empirically to investigating the effects of the writing process on understanding, to the relationships this has with effective communication, and to the factors influencing its development.

Our fundamental claim is that the knowledge-constituting process through which understanding is realized is based on a system designed for action, in which each step is provisional and forms only part of a path to the writer's final goals. By contrast, the knowledge-transforming process is based on a system designed for reflection, in which objects produced by action can be surveyed and manipulated to satisfy goals. Mentally, this function of recording actions as stable objects is performed by episodic memory. Writing augments this by providing an external record of the path of our thought and hence enhances our capacity for reflection. But this very feature has led research on writing to focus on the reflective processes involved in manipulating objects and to neglect the processes involved in producing them. Our aim in this article has been to suggest how we can think about this process and to indicate how we can explore its characteristics.

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